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EXTENDED MID-INFRARED (IR) TUNING OF A Cr2+:CdSe LASER

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Extended Mid-IR Tuning of a Cr^{2+}:CdSe Laser

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Abstract: We report 2450-3400 nm laser operation from a Cr^{2+}:CdSe laser, pumped by a Q-switched Tm,Ho:YLF laser. Laser tuning was achieved over a large part of the 2100-3400 nm emission cross section bandwidth using a simple grating-tuned resonator.
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1. Introduction

Research over the past few years[1-4] has shown Cr^{2+}:chalcogenide II-VI materials to have the potential for broad tuning in the mid-infrared. The possibility of a single laser that could tune from 2-3.5 μm has been of interest for applications in spectroscopy and chemical detection. However until this time no Cr^{2+} laser has tuned out farther than 3.04 μm[5]. Thermal effects in Cr^{2+} materials at moderate absorbed power levels and limitations of optical coatings have prevented laser operation in the long wavelength tail of the emission spectra. By going to a simple resonator with extremely broadband optics, using a large diameter pump beam, and operating at a pulse repetition rate slow enough to mitigate thermal effects, we have demonstrated long wavelength operation of Cr^{2+}:CdSe out to 3.4 μm.

2. Cr^{2+}:CdSe Sample

The crystal used for this demonstration was a 12-mm long, diffusion-doped Cr^{2+}:CdSe sample made and anti-reflection coated by Cleveland Crystals. This sample absorbed 63% of incident 2.05-μm pump light, and was AR coated for 2.4-2.9 μm operation. In earlier work, crystals from the same batch as this sample have shown tuning from 2.3-2.9 μm[3]. Typical losses in these samples were ~5% per pass at the lasing wavelengths.

3. Emission Cross Section Measurement

To investigate the feasibility of extended tuning past 3 μm in Cr^{2+}:CdSe, the emission cross section was measured using a PbSe detector and a 15-cm spectrometer calibrated to a blackbody reference source. With slit spacings of ¾ mm (limited by detector sensitivity), the effective resolution was ~20 nm FWHM, adequate for measurement of Cr^{2+} broadband fluorescence. Fluorescence from Cr^{2+}:CdSe was measured, under 1-W CW excitation by a 2.05-μm Tm,Ho:YLF laser. Cr^{2+}:ZnSe fluorescence was measured as well, for comparison purposes. The fluorescence data were then used to produce the emission lineshape function, which was used along with the fluorescence lifetime to calculate the emission cross section. The emission cross sections for Cr^{2+} in CdSe and ZnSe calculated by this method are shown in Fig. 1. Note that the emission cross section for Cr:CdSe extends to much longer wavelengths than that of Cr:ZnSe, allowing for the possibility of extended tuning in the mid-infrared past 3.4 μm. Note that it does not appear likely that Cr^{2+}:ZnSe would tune out past 3 μm without exceptionally intense pumping.

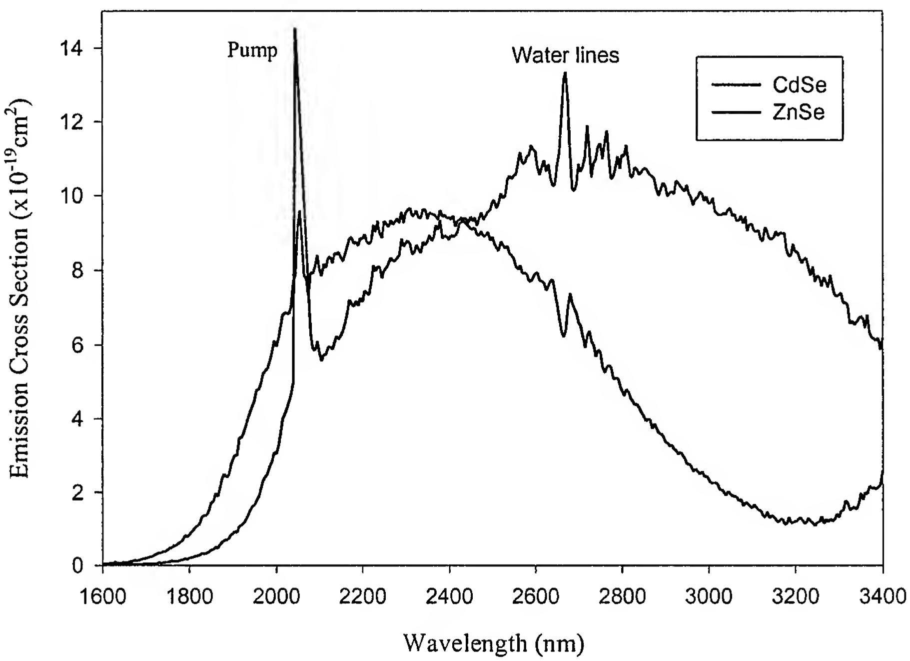

Figure 1. Cr^{2+} Emission Cross Sections. Increasing trend beyond 3.2 μm in ZnSe is due to 2nd order diffraction of short wavelength emission.

4. Cr:CdSe Laser Tuning

The laser tuning experimental setup consisted of a simple end-pumped Cr^{2+}:CdSe standing wave laser using a Tm,Ho:YLF laser for excitation, a diffraction grating for tuning, and a 15-cm spectrometer and pyroelectric detector for wavelength measurements. A schematic of the setup is shown in Fig. 2. The Tm,Ho:YLF laser was Q-switched at 3 kHz (400 ns FWHM pulses) and focused to a 1-mm beam diameter inside the Cr:CdSe rod. The laser rod was held in a water-cooled heat sink. Positive thermal lensing inside the laser rod provided the cavity stability. The output from the Cr^{2+}:CdSe laser was the ~20% specular reflection from the diffraction grating, and the feedback was provided by the first order diffraction. Changing the grating angle changed the Cr^{2+}:CdSe laser wavelength. The output was sent through a 15-cm monochromator and detected by a chopped pyroelectric power meter.

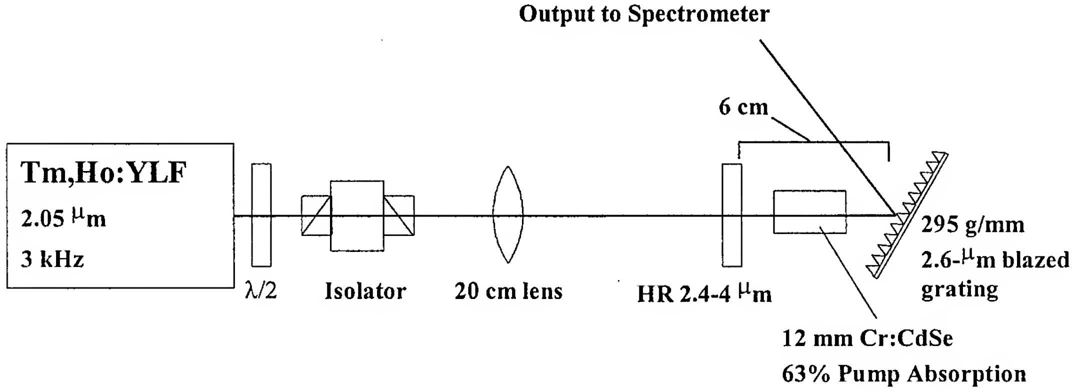

Figure 2. Tuning Experiment Setup

The absorbed power laser threshold of the Cr^{2+}:CdSe laser was measured as a function of output wavelength. The result is shown in Fig. 3. The experiment validates the emission cross section

measurements which indicate significant gain out to long wavelengths past 3 μm. A broad tuning range of 2450 to 3400 nm was demonstrated, the longest wavelength tuning yet achieved for a Cr^{2+} laser. Tuning below 2450 nm has previously been demonstrated, but was not possible for this experiment due to a cutoff in the input coupler reflectivity at 2450 nm. With appropriate broadband optics (such as metallic mirrors), pulsed operation over the range of 2.3-3.4+ μm from the Cr^{2+}:CdSe laser should be possible. The fundamental limits on the tuning range are ground state absorption at short wavelengths and the onset of thermal effects and damage at long wavelengths.

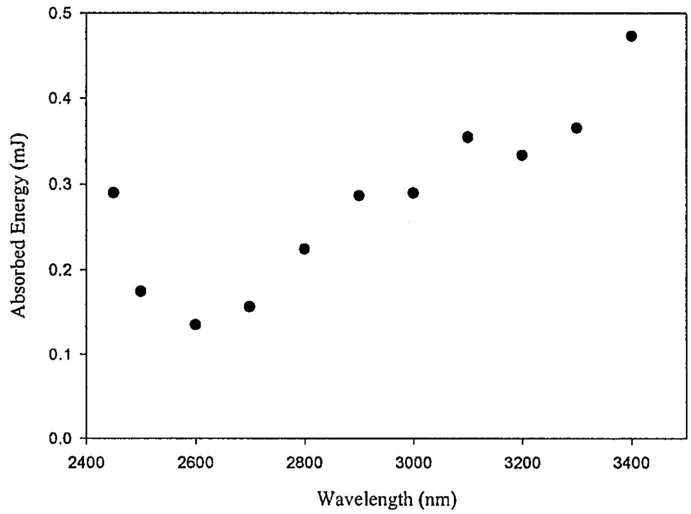

Figure 3. Cr^{2+}:CdSe Laser Threshold vs. Wavelength

As shown in Fig 3, laser threshold increased towards the edges of the tuning curve due to diminishing gain. But in addition, the threshold was further increased by nonradiative relaxation and thermal lensing which increased as absorbed power increased. Past a certain absorbed power the thermal effects prevented laser operation altogether. To achieve the maximum tuning range in the experiment, we had to mitigate these thermal effects at the expense of efficiency. We used a large pump beam diameter to lessen the radial temperature gradient experienced by the cavity mode. We also used a Q-switched, 3-kHz, pump beam to reduce the average absorbed power and to reach threshold with a large beam diameter.

Our experiment was designed to demonstrated maximum tuning range. Optimizing efficiency and output power will require sophisticated compensation of thermal effects. One possible technique under consideration is thin disk cooling which reduces resonator loss and improves heat transfer out of the crystal.

5. Summary

With broadband optics, and mitigation of thermal effects, a Cr^{2+}:CdSe laser tuned from 2450 nm to 3400 nm, well past the previous limit of 2.9 μm. This tuning agreement is in excellent agreement with emission cross section calculations. The broad tuning range of Cr^{2+}:CdSe makes it look promising for tunable laser applications, despite its poor thermal conductivity. We plan to demonstrate useful tuning range from 2.1-3.4 μm with a thin disk approach to mitigate thermal effects and improve operating efficiency.

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